1-1-1972

Cardiovascular Response To Exercise In Water

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CARDIOVASCULAR RESPONSES TO EXERCISE IN WATER

DENNIS WAYNE ATEN

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CARDIOVASCULAR RESPONSES

TO EXERCISE IN WATER

(TITLE)

BY

DENNIS WAYNE ATEN

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN PHYSICAL EDUCATION

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1972
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
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May 5, 1972 — DATE

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May 5, 1972 — DATE

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ACKNOWLEDGEMENTS

The writer wishes to express his appreciation to his advisor, Dr. Thomas Woodall, for his guidance and direction in this study.

Appreciation is also extended to Dr. Robert Carey and Dr. William Buckellew for their constructive criticism of the development of this paper.

To Mr. James Conboy, appreciation is extended for his original thoughts upon which this paper is based.

The writer wishes to thank and show his appreciation to his wife, NaDean, for the many hours of work, patience, and encouragement given during the preparation of this study.

The writer also wishes to thank all the subjects who made this possible.

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Chapter I

INTRODUCTION

The utilization of water exercise to accomplish cardiovascular conditioning in conjunction with therapeutic benefits has recently gained interest in athletic rehabilitation. Injuries that limit athletes to partial weight bearing pose the problem of maintaining cardiorespiratory conditioning during rehabilitation.

Underwater exercise involving non-ballistic movements has been used to treat "sore" or "stiff" muscles for many years. This form of treatment has been utilized more recently in athletics to "limber up" tight or strained musculature. Since a portion of an individuals weight is bouyed up in water, activity such as running in water at chest level is not a total weight bearing activity. A program of running in water at chest level might allow an injured athlete to resume competitive activity sooner.

In the early 1960's the Air Force Academy used swimming pool activity as a part of the two practice sessions per day in the early fall football program. It was initially used as a refreshing activity after a workout in hot weather but it was observed that athletes who employed continuous gentle activity in the water for 15 to 20 minutes, seemed to complain less of stiffness and soreness. This phenomena was not too surprising since it is recorded throughout history that injured warriors and athletes have sought streams and pools to sooth their aching muscles. Few athletic programs, however, have included exercise in water as a therapeutic agent for the initial soreness of early season workouts.

Since therapeutic pools are widely used in physical therapy with handicapped children, a relationship between physical therapy and athletic rehabilitation was observed. Exercise in water is used for those with neurological and muscular disorders in physical therapy to take advantage of buoyancy in the water to achieve relaxed motion. Water can be used to aid movement by modifying the effect of gravity or, in varying degrees, used as a resistance to movement by requiring forceful motion through water. Muscle soreness caused by minute tears in muscle tissue can often be alleviated through non-ballistic movement in water which can aid circulation and exercise the area without danger of irritating or further traumatizing the area. Underwater exercise has a sound theoretical basis for use in rehabilitation and has gained acceptance as an adjunt to other physical therapy techniques.

An added benefit of exercise in water becomes evident as individuals with injuries too painful for weightbearing, safely achieve activity through increased buoyancy. Running in water at chest level allows patients with ankle sprains to get relatively pain-free normal muscular activity around the ankle joint, without the dangers imposed by full weightbearing. Questions arose concerning the work load placed on the athlete during the water exercise. Was the work sufficient to stress the heart and lungs to gain any cardiovascular conditioning effects? Would this activity stop or retard the deconditioning that normally takes place during convalesence from an athletic injury?

With these questions in mind some athletic trainers have developed under water activity programs that include repetitive resisted movements (i.e. running certain distances in water at chest level) as a work load.

Statement of the Problem

The purpose of this study was to determine the amount of stress placed upon the cardiovascular system while running in water at chest level as measured by heart rate elevations.

Limitations of the Study

Twenty-five subjects representing two sports were studied. No attempt was made to include all body types, sizes, and shapes or define individual or group levels of physical condition.

This study was an exploratory investigation into the possible cardiovascular benefits of a water exercise program.

Definitions of Terms

The following terms are defined as they were employed in this investigation.

Lap: A lap is two widths of a swimming pool that is 43 feet wide.

Deconditioning: Deconditioning is the loss of cardiovascular condition due to the lack of physical training.

Running in water: Running in water is the activity where the subject runs with knee high action in water at chest level with enough speed to complete the run as fast as possible.

Hands in the Water: Hands in the water is a phase of the running in water exercise where the athlete is allowed to use his arms and hands to help propel him through the water.

<u>Hands out of the water:</u> Hands out of the water is a phase of the running in water exercise where the athlete is not allowed to use his arms or hands to help propel himself through the water.

<u>Sprint phase:</u> The sprint phase is a phase of the running exercise where the athlete was requested to complete two laps as rapidly as possible.

<u>Endurance phase:</u> The endurance phase is a phase of the running in water exercise where 14 laps were completed as rapidly as possible.

Chapter II

RELATED LITERATURE

This review of literature is divided into three portions: Movement in Water, Heart Rates-Predictors of Work Out-Put, and Training Effect Heart Rates.

Movement in Water

A review of the literature indicated that little research has been reported related to the problems of running in water. Karpovich and Sinning[1] stated several reasons for the lack of research concerning energy costs during aquatic activities. They felt this type of study had no practical military value, required special equipment, and could not be performed in a laboratory. Only recently has there been an interest in the energy cost of certain competitive swimming strokes. In addition, the aspects of running in water have a more limited range of interest than most aquatic activites.

Written material is available concerning the relationship of the physical properties of water and their effect on movement through that medium. Archimedes principle[2] states that a body floating or submerged in liquid is buoyed up by a force equal to the weight of the

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[1]Peter V. Karpovich and Wayne E. Sinning, Physiology of Muscular Activity (Philadelphia: W. B. Saunders Company, 1971), p. 130.

[2]Harvey E. White, Modern College Physics (3rd, ed, Princeton, New Jersey: D. Van Nostrand Company, Inc., 1956), p. 219.

liquid displaced. The same medium that buoys up a body gives resistance to movement through it. White[3] stated that friction or resistance is directly proportional to the velocity at low speeds. There is more involved to the work load in water exercise than water resistance, however. Lowman and Roen[4] stated that, in water, there seems to be greater relative activity of the muscles of joint stabilization than in other muscle training work. It appears that the buoyancy of the water prevents the body from stabilizing itself to fixed surfaces.

Heart Rates-Predictors of Work Out-Put

To learn more about the physiological cost of work in water, heart rates might be investigated. Before considering exercise and recovery heart rates, some background concerning resting heart rates, appears necessary. Astrand[5] claims that it has been established that individuals with physical endurance have lower resting heart rates when compared to the general populace. Karpovich[6] warns that care must be taken however, in evaluating resting heart rates near the time of competition. In place of a "resting" pulse there might be a "start" pulse accelerated by the excitement of anticipation. In a group of weight lifters whose normal resting heart rate averaged 72 beats per minute (B.P.M.), a range of 135 to 160 B.P.M. was reported just prior to a

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[3]Ibid., p. 219.

[4]Charles L. Lowman and Susan G. Roen, Therapeutic Use of Pools and Tanks (Philadelphia: W. B. Saunders Company 1952), p. 37.

[5]Per-Olaf Astrand and Kaare Rodahl, Textbook of Work Physiology (New York: McGraw-Hill Book Company, 1970), p. 403.

[6]Karpovich, Op. cit., p. 202.

contest.

The American Heart Association[7] suggests that the normal resting heart rate range be considered between 50 to 100 with a tendency for the rate to be lower in trained athletes than non-trained individuals. There was no significant correlation between heart rates and physical fitness when the exceptionally low rates that belonged to the highly trained athletes were eliminated.

The heart rate is one parameter that can provide information relating to the effect of activity or work on the human organism. According to Mathews and Fox[8] there is a linear relationship between work load and an increased heart rate over the resting value. Heart rates may level out as they approach maximum. Morehouse and Miller[9] found a more curvilinear relationship as shown below.

Work Load (Foot Pounds / Minute)	Heart Rate / Minute	Heart Rate Increase
Resting	75	---
2,000	105	30
4,000	132	27
6,000	154	22
8,000	177	23
10,000	198	21

[7]Lawrence Morehouse and Augusters Miller, Jr., Physiology of Exercise (5th Ed: St. Louis : C. V. Mosby Company, 1967), p. 97

[8]Donald K. Mathews and Edward L. Fox, The Physiological Basis of Physical Education and Athletics (Philadelphia: W. B. Saunders Company, 1971), p. 155.

[9]Morehouse, op, cit., p. 99. Citing E. C. Schneider, Physiology of Muscular Activity (2nd Ed;, Philadelphia: W. B. Saunders Co., 1939).

Maximum heart rates have been found to be well over 200 B.P.M., however, Balke[10] proposes that heart rates of 180 be used to measure cardiorespiratory capacity. At rates above 180 B.P.M. the heart can neither fill or empty completely.

Astrand,[11] for purposes of predicting maximal oxygen uptakes, gave average maximum heart rates according to age. His studies indicated that maximum heart rates for 15 year olds averaged about 210, 25 year olds averaged about 200, and 35 year olds about 190. In one study 15-17 year old girls have been able to elevate heart rates to an average of 250 after a 5 kilometer ski run. One girl attained a maximum heart rate of 270.

McArdle and others[12] found that heart rates elevate rather quickly. In their study, trained heart rates reached 180 B.P.M. in a 2 mile race within 28 seconds, and within 10 seconds for a 220 yard race. They noted there were higher peak heart rates in longer races.

Morehouse and Miller[13] found that speed work in track elevated heart rates faster and higher than other forms of work. Weight lifting was the lowest in heart rate elevation.

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[10] David L. Costill, Distance Running (Washington, D. C. American Association for Health, Physical Education, and Recreation, 1968), p. 14.

[11] P. O. Astrand: Ergometry-Test of "Physical Fitness" (Varborg, Sweden, A. B. Cykelfabriken Monark) cited by Peter V. Karpovitch and Wayne I. Sinning, Physiology of Muscular Activity (Philadelphia: W. B. Daunders Company, 1971), p. 199.

[12] W. D. McArdle and others, "Telemetered Cardiac Response to Selected Running Events," Journal of Applied Physiology 23:566, 1967. Cited by Karpovich, op. cit., p. 205.

[13] Morehouse, op, cit., p. 100.

Training Effect Heart Rates

It would appear, in order to improve the exercise tolerance of the heart, the intensity of the training has to be above a rather high threshold value.[14] According to Carlsten and Grimby[15] half hour workouts four times a week that raise heart rates to 115-125 B.P.M. are considered of moderate intensity and sufficient to lead to maximal activity, but not enough to affect maximum O_2 uptake or heart volume. Heart rates of 170 to 180 B.P.M. are considered a very heavy work load. Five weeks of training with work loads of that intensity showed increases in both maximum O_2 uptake and heart volume.

Karnoven[16] has a simple but classic method for determining the heart rate necessary to improve cardiovascular function. He has developed a formula which equates 70 per cent of the maximum working heart rate as sufficient for cardiovascular conditioning...Conditioning Heart Rate = .70 (maximum heart rate - resting heart rate) + resting heart rate.

Cooper[17] states that 60 percent of an individuals maximum heart rate is a good energy level for producing a training effect. He feels that approximately 150 B.P.M. is a good representative of that level

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[14]Ernst Jokl, Heart and Sport (Springfield, Illinois: Charles C. Thomas, 1964), p. 52.

[15]Arne Carlsten and Gunnar Grimby, The Circulatory Response to Muscular Exercise in Man (Springfield, Illinois: Charles C. Thomas, 1966), p. 69-70.

[16]Fred W. Kaach, and John L. Boyer, Adult Fitness, Principles and Practice (Greeley, Colorado: All American Productions and Publications, 1968), p. 29.

[17]Kenneth Cooper, The New Aerobics (New York: M. Evans and Company, 1970), p. 155.

for healthy people under 30. He adds, however, that the duration of activity is also related to the training effect. The more time spent in daily workouts, the less intense the workouts have to be to produce a training effect. For most persons, a heart rate of 150 B.P.M. represents about 60 per cent of working capacity and need be performed only 10 minutes per day for a training effect.

Parameters	Training Effect				
Daily Time Requirements (Min.)	180	90	45	20	10
Working Capacity (% of Max.)	20	30	40	50	60
Heart Rate (B.P.M.)	110	120	130	140	150

Graham[18] agrees that for a training effect the heart rate should reach a peak equal to 60 per cent of the maximum range. He states that this rate should be sustained for several minutes during a 30 minute workout. He feels that work sufficient to burn 400 to 450 calories in 30 minutes is almost certain to be sufficient to achieve a cardiovascular training effect.

Astrand[19] cites studies in 1957 by Karnoven in stating that attaining 60 per cent of the capable heart rate range is necessary in order to produce a decrease in the working heart rate.

Costill[20] and DeVries[21] also cite Karnoven in discussing 60 per

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[18] M. F. Graham, Prescription for Life (New York: David McKay Company, Inc., 1966), p. 93-95.

[19] Astrand, op. cit., p. 417.

[20] Costill, op. cit., p. 19.

[21] H. A. DeVries, Physiology of Exercise for Physical Education and Athletics, (Dubuque, Iowa: William C. Brown Co., 1966).

cent of the working heart rate range as a basis for finding a conditioning heart rate.

Summary

It has been shown that, due to the density and buoyancy of water, work done in this medium is affected differently than work done in air.

Authorities tend to agree that heart rates above certain levels are necessary to achieve cardiovascular conditioning effects. Heart rates of 120-160 B.P.M. were cited as conditioning or training affect heart rates. These heart rates were usually determined by a formula using 60 or 70 per cent of the working heart rate. The working heart rate was defined as the difference between the resting pulse rate and the maximum pulse rate.

If heart rates in water exercise can consistently be raised to the training effect levels previously discussed, it would follow that water exercise might be considered as a cardiovascular conditioner.

Sprint Group (Group S)	Endurance Group (Group E)
2 minute warm-up	2 minute warm up
2 lap sprint, hands in water	7 lap endurance, hands in water
2 minute recover	7 lap endurance, hands out of water
7 laps endurance, hands out of water	2 minute recovery
7 laps endurance, hands in water	2 lap sprint, hands in water
2 minute recovery	2 minute recovery

Subjects were placed in these two groups to attempt to study the heart rate response to different methods and intensities of running in water at chest level.

Twenty-five varsity athletes at Eastern Illinois University volunteered to serve as subjects. Thirteen were members of the spring football team and twelve were members of the baseball team. Notation was made of the height, weight, age, sport, and position, of each subject on his individual data sheet.

Subject Preparation

When each subject arrived at the swimming pool dressed in a swimming suit, he was given directions for his part in the test. After the subject understood what was expected of him, he was asked to lie down on a raised portion of the swimming pool deck. His chest was shaved and debrided in the area of the left distal border of the sternum and about four inches to the left of the sternum at about the level of the sixth or seventh rib. (see Figure 1) Cotton tipped applicators were used to scrub the area with an abrasive contact gel. Adhesive

Figure 1

THE SUBJECT PREPARED FOR E.C.G. TELEMETRY

IN WATER EXERCISE

snap electrodes with contact gel were placed in the debrided areas after they were wiped clean. A patient cable connected the electrodes to the RKG 100 (Hamilton-Standard, Windsor Locks, Conn.) Radio Transmitter and all connections were secured with waterproof plastic tape. In a seated position, a football helmet was placed on the head of the subject with the radio transmitter fastened to the top of the helmet with a strong plastic adhesive tape. The radio transmitter was protected from the water by a plastic bag. The patient cable was taped to the shoulder to keep the excess length of wire out of the way of the subject and not restrict normal movement. At this time the subject was again instructed concerning his activities during the test.

Heart Rates

A seated E.C.G. tracing was obtained to test the equipment and to depict the resting heart rate. The subject then stood at the edge of the pool and a large-faced clock with a sweep second hand was set at zero. As the subject entered the water the clock was started and a second E.C.G. tracing was taken to record the effect that entry into 26° C. ($\pm$ 1° C.) water had on the heart rate. The subject warmed up by running slowly in the water, incorpating total body movement, for two minutes. A third E.C.G. was taken to record the effects of the warm up and at exactly two minutes after entry into the water, the active exercise began. E.C.G. tracings were then taken at the end of each lap and at the end of each recovery period.

Chapter IV

ANALYSIS OF DATA

To determine the amount of stress placed on the cardiovascular system by running in water at chest level, heart rates were taken on 25 college athletes. Heights, weights, and body surfaces of the subjects were recorded to determine if differences in these anthropometric measures would be a factor in elevating heart rates during water exercise.

Data Conversion

Heart rates, determined from QRS complexes on electrocardiograph paper by a heart rate ruler, were reported in beats per minute. Lap times were recorded in seconds. Weights were converted from pounds to kilograms and standing height from inches to centimeters. Body surfaces were reported in square meters and determined by the following formula[1]:

$S = 0.007184 \times H^{0.725} \times W^{0.425}$

Statistical Treatment

Data were collected for 16 variables on each of the 25 subjects and punched into I.B.M. cards. These variables included height, weight, body surface, heart rates at various stages of the test, and times for the sprint and endurance phases of the running in water exercise.

The subjects were grouped according to the order in which they completed the test and according to the sport in which they participated.

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[1]C. F. Consolazio, R. E. Johnson, and L. J. Pecora, Physiological Measurements of Metabolic Functions in Man, (New York: McGraw-Hill Book Company, Inc., 1963), p. 32.

The subjects who ran the sprint phase of the test first were placed in Group S. Subjects who ran the endurance phase of the test first were placed in Group E. For the purpose of additional analysis football players were placed in Group FB and baseball players were placed in Group BB.

Computerized programs were employed to compare groups with a *t* ratio[2] and develop pertinent inter-correlations[3] between variables. The .05 level of confidence was selected to denote statistically significant comparisons or relationships.

Mean Heart Rates

Figure 2 describes the pattern of mean heart rates during the course of the test. Heart rates were elevated in all active phases of the test to levels considered in the literature to have a cardiorespiratory training effect.

Group S vs. Group E Comparisons

Table I shows few significant differences between Group S and Group E. Peak and mean sprint heart rates, endurance recovery heart rates, and mean endurance heart rates without using the arms were significantly higher in Group E.

Group FB vs. Group BB Comparisons

Table II shows the comparison between football and baseball

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[2] A. J. DePietro and J. J. LeDuc, "Student *t* Scores for Means Between Groups", (Charleston: Eastern Illinois University, May, 1964).

[3] W. J. Dixon, "BMDO 34 Correlation with Item Deletion", (Berkeley: University of California, Biomedical Computer Programs).

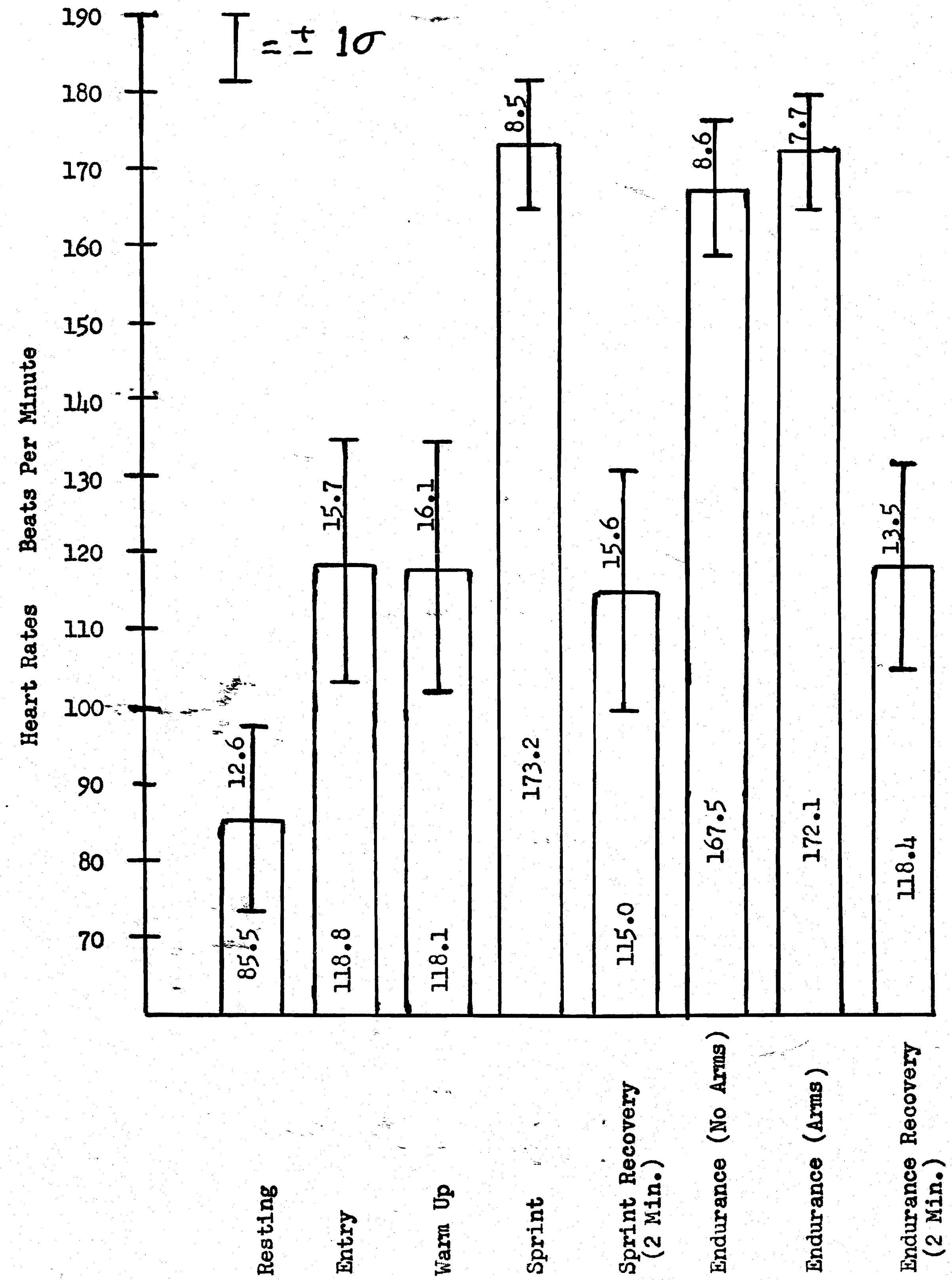

Figure 2

Mean Heart Rates and Standard Deviations

TABLE I

t Scores Group S vs. Group E

Variable	Group Means Sprint	Group Means Endurance	t Score	df	Level of Confidence
1. Weight (KG)	84.47	89.19	1.13	23	.30
2. Height (CM)	180.79	184.15	1.56	23	.20
3. Body Surface (SqM)	2.05	2.12	1.31	23	.30
4. Resting Heart Rate	84.17	86.77	0.51	23	.70
5. Entry Heart Rate	118.45	119.08	0.09	22	---
6. Warm Up Heart Rate	115.18	120.62	0.82	22	.50
7. Peak Sprint Heart Rate	170.83	179.38	2.09	23	.01
8. Peak Endurance Heart Rate	178.25	176.62	0.58	23	.60
9. Recovery Sprint Heart Rate	120.67	109.77	1.82	23	.10
10. Recovery Endurance Heart Rate	109.33	126.69	4.18	23	.001
11. Mean Sprint Heart Rate	168.79	177.19	2.79	23	.02
12. Mean Endurance Heart Rate (Total)	168.85	170.33	0.50	23	.70
13. Mean Endurance Heart Rate (Using Arms)	174.61	169.75	1.63	23	.20
14. Mean Endurance Heart Rate (No Arm Use)	163.85	170.89	2.20	23	.05
15. Mean Sprint Time (Sec.)	64.67	61.08	1.10	23	.30
16. Mean Endurance Time (Sec.)	495.42	476.15	0.95	23	.40

TABLE II

t Scores Group BB vs. Group FB

Variable	Group Means Baseball	Group Means Football	t Scores	df	Level of Confidence
1. Weight (KG)	80.37	92.99	3.69	23	.01
2. Height (CM)	180.38	184.54	1.99	23	.10
3. Body Surface (SqM)	2.00	2.17	3.40	23	.01
4. Resting Heart Rate	88.33	82.92	1.08	23	.30
5. Entry Heart Rate	112.27	124.31	1.99	22	.10
6. Warm Up Heart Rate	118.73	117.62	0.16	22	.90
7. Peak Sprint Heart Rate	171.50	178.77	2.34	23	.05
8. Peak Endurance Heart Rate	175.17	179.46	1.59	23	.20
9. Recovery Sprint Heart Rate	113.92	116.00	3.26	23	.01
10. Recovery Endurance Heart Rate	114.25	122.15	1.50	23	.20
11. Mean Sprint Heart Rate	169.96	176.12	1.90	23	.10
12. Mean Endurance Heart Rate (Total)	165.87	173.08	2.83	23	.01
13. Mean Endurance Heart Rate (Using Arms)	168.60	175.29	2.38	23	.05
14. Mean Endurance Heart Rate (No Arm Use)	163.07	171.62	2.81	23	.01
15. Mean Sprint Time (Sec.)	69.33	56.77	5.99	23	.001
16. Mean Endurance Time (Sec.)	529.92	447.08	6.50	23	.001

players for all of the variables. Group FB was significantly heavier and had a greater body surface than Group BB.

When compared with the football players, the baseball players showed significantly lower peak sprint heart rates, more rapid recovery heart rates from the sprint run, lower mean heart rates during both phases of the endurance run. It should be pointed out, however, that football players ran significantly faster than baseball players, in both the sprint and the endurance phase.

Correlations

Only four of the 17 intercorrelations studied were statistically significant at the .01 level of confidence. The -.706 coefficient between the elapsed time for the endurance portion and the mean endurance heart rate was expected. The three other significant correlations (15, 16, and 17) indicated similar heart rates were achieved regardless of arm involvement, that mean sprint and mean endurance heart rates were similar, and the peak sprint heart rates and peak endurance heart rates were significantly related.

Correlation numbers 1, 2, 7 and 8 were significant at the .05 level and seemed to indicate a relationship between the speed in the water and the body weight and surface area. The heavier persons, and those with more body surface, seemed to move through the water faster than subjects weighing less and with smaller body surface areas.

Discussion of Findings

One of the more interesting sidelights of the study pertains to the comparisons of the size and speed in water between the football and baseball players. Football players were larger and also completed the

TABLE III

Correlations for 25 Subjects

Correlation Number	Variables	Correlation Coefficient	Level of Confidence
1.	Weight - Time for Sprint Portion	-0.40157	.05
2.	Weight - Time for Endurance Portion	-0.40750	.05
3.	Weight - Peak Sprint Heart Rate	0.07547	N.S.
4.	Weight - Peak Endurance Heart Rate	-0.05763	N.S.
5.	Weight - Mean Sprint Heart Rate	-0.04459	N.S.
6.	Weight - Mean Endurance Heart Rate	0.16893	N.S.
7.	Body Surface - Time for Sprint Portion	-0.42670	.05
8.	Body Surface - Time for Endurance Portion	-0.42263	.05
9.	Body Surface - Peak Sprint Heart Rate	0.10568	N.S.
10.	Body Surface - Peak Endurance Heart Rate	-0.02464	N.S.
11.	Body Surface - Mean Sprint Heart Rate	-0.00709	N.S.
12.	Body Surface - Mean Endurance Heart Rate	0.18286	N.S.
13.	Time for Sprint Portion - Mean Heart Rate	-0.47546	.05
14.	Time for Endurance Portion - Mean Heart Rate	-0.70571	.01
15.	Arms in Water Heart Rate - Arms Out of Water Heart Rate	0.83139	.01
16.	Mean Sprint Heart Rate - Mean Endurance Heart Rate	0.49664	.01
17.	Peak Sprint Heart Rate - Peak Endurance Heart Rate	0.53934	.01

N.S. = Not significant for the study

test in a much faster time. Possibly the heavier football players were able to get more traction on the bottom of the pool and therefore could move more rapidly through the water. Speculation would cause one to wonder if anything inherent in either sport, other than size, would be a factor affecting the running speed. The investigator observed that the football players, as a group, seemed to be more motivated toward higher levels of effort, however this impression could have been due to facial expressions or other intangible facets of the test.

Chapter V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

It was the purpose of this study to determine, within the limits and scope of the investigation, the cardiovascular effects of running in water at chest level. Exercise and recovery heart rates were studied as they related to the size of the subject and the speed and method of running in water.

The subjects were twelve baseball players and thirteen football players from Eastern Illinois University. Each subject was given a test that consisted of sprint and endurance running through water at chest level for a total of 16 laps in a swimming pool 43 feet wide. Subjects used their arms and hands for assistance during nine of the laps. Heart rates were determined at the completion of each lap throughout the test by means of a radio-telemetered electrocardiogram.

Conclusions

The data gathered in this investigation would indicate a basis for the following conclusions:

1. Heart rates increase sufficiently during running in water at chest level to have value in cardiovascular conditioning.
2. Sprint and endurance running in water produce similar heart rates.

3. In water, heavier subjects run faster than lighter subjects.
4. There is a high relationship between speed of activity in water and heart rate elevation.
5. Therapeutic exercise in water programs can be developed for athletes to aid in cardiovascular conditioning where weight bearing activities are contraindicated.

Recommendations for Further Study

The following recommendations are based on the findings of the study:

1. Additional studies of this nature should be undertaken using different types of subjects, (track men, basketball players, etc.).
2. A study should be designed to determine the length of time needed for activity in water to approximate the conditioning levels of actual workouts for each of the various sports.
3. A study should also be instigated to determine optimum amounts of exercise in water to attain both therapeutic benefits and cardiovascular conditioning.

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APPENDICES

APPENDIX A. DATA SHEET

Name____________________ Date____________ Time____________

Sport__________________ Position____________ Water Temp.__________

Height Inches________ CM________ Weight____ Pds____ KG____

Age____________ Year in School____________

		Heart Rates	Time	Comments
Prior to Warm up				
After Warm up				
All out(Legs (and (Arms (	1 lap			
	2			
	3			
	4			
Endurance	1 lap			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	13			
	14			
	15			
	16			
All out(Legs (and (Arms (	1 lap			
	2			
	3			
	4			
Recovery				

APPENDIX B: INDIVIDUAL DATA (Baseball Players)

Identification	Weight (kg)	Height (cm)	Resting Heart Rate	Entry Heart Rate	Warm Up Heart Rate	Peak Sprint Heart Rate	Peak Endurance Heart Rate	Recovery Sprint Heart Rate	Recovery Endurance Heart Rate	Mean Sprint Heart Rate	Mean Endurance Heart Rate (total)	Mean Endurance Heart Rate (using arms)	Mean Endurance Heart Rate (no arms)	Sprint Time	Endurance Time
B01E	75.0	183.0	99	128	122	180	175	125	140	177.5	167.8	165.5	170.0	58	477
B02E	79.5	188.0	73	93	127	173	187	115	125	173.0	175.8	170.6	181.0	67	518
B03E	96.4	180.5	89	108	112	163	163	88	105	163.0	157.6	155.7	159.4	82	590
B04E	65.9	171.5	78	108	138	195	185	120	125	195.0	168.5	176.2	160.7	66	536
B05E	84.1	187.0	110	140	124	174	165	107	115	173.0	153.2	150.7	155.7	67	533
B06E	68.2	173.0	81	86	90	170	173	96	104	167.5	164.3	170.4	158.1	80	541
B07S	97.7	190.5	88	112	118	173	187	124	115	169.0	175.3	178.6	171.9	73	523
B08S	80.9	180.5	102	120	133	160	173	135	104	160.0	167.3	170.1	164.4	65	473
B09S	72.7	175.5	73	127	100	165	175	125	115	165.0	170.8	174.1	167.4	68	497
B10S	79.5	183.0	82	98	112	165	170	122	110	162.5	161.2	166.0	156.3	70	535
B11S	84.1	174.0	88	115	130	170	173	118	118	165.0	165.0	171.1	158.9	70	565
B12S	80.5	178.0	97	---	---	170	176	92	95	169.0	163.6	174.2	153.0	66	535

B = Baseball Player
E = Endurance Phase First
S = Sprint Phase First

APPENDIX C: INDIVIDUAL DATA (Football Players)

Identification	Weight (kg)	Height (cm)	Resting Heart Rate	Entry Heart Rate	Warm Up Heart Rate	Peak Sprint Heart Rate	Peak Endurance Heart Rate	Recovery Sprint Heart Rate	Recovery Endurance Heart Rate	Mean Sprint Heart Rate	Mean Endurance Heart Rate (total)	Mean Endurance Heart Rate (using arms)	Mean Endurance Heart Rate (no arms)	Sprint Time	Endurance Time
F01E	100.9	185.5	68	102	93	180	175	98	110	177.5	170.3	168.9	171.7	55	451
F02E	89.5	183.0	86	145	150	185	185	118	138	185.0	178.4	180.0	176.9	57	439
F03E	106.8	195.5	78	138	138	188	178	125	143	184.0	175.8	175.3	176.4	51	429
F04E	90.9	180.5	86	118	110	175	175	115	130	170.0	172.0	171.0	172.1	57	432
F05E	88.6	180.5	82	125	112	182	182	114	128	182.0	177.5	177.2	177.7	59	458
F06E	95.5	185.5	90	110	117	174	174	110	120	169.5	170.3	170.3	170.4	58	425
F07E	95.5	188.0	108	125	115	185	177	115	128	180.0	174.0	172.0	175.9	61	446
F08E	90.9	185.5	81	108	110	178	175	77	140	174.0	173.1	172.4	173.7	56	456
F09S	93.2	183.0	75	115	98	175	178	110	102	172.5	163.1	175.4	160.7	60	464
F10S	79.5	180.5	105	140	140	187	192	148	120	186.0	184.1	189.0	179.1	54	414
F11S	102.3	185.5	68	121	93	172	180	133	120	166.0	172.0	175.6	168.3	53	436
F12S	88.6	185.5	64	133	125	170	175	120	100	170.0	161.6	168.7	154.4	64	527
F13S	86.4	180.5	87	136	128	173	187	125	109	173.0	177.9	182.1	173.7	53	435

F = Football
E = Endurance Phase First
S = Sprint Phase First

APPENDIX D: MEANS AND STANDARD DEVIATIONS FOR ALL SUBJECTS

Variable	Mean	Standard Deviation	Number of Subjects
1. Weight (kg)	86.9239	10.5263	25
2. Height (cm)	182.5400	5.5396	25
3. Body Surface (Sq. M.)	2.0880	0.1450	25
4. Resting Heart Rate	85.5200	12.5770	25
5. Entry Heart Rate	118.7917	15.6677	24
6. Warm Up Heart Rate	118.1250	16.1011	24
7. Peak Sprint Heart Rate	175.2800	8.4436	25
8. Peak Endurance Heart Rate	177.4000	6.9404	25
9. Recovery Sprint Heart Rate	115.0000	15.6498	25
10. Recovery Endurance Heart Rate	118.3600	13.4626	25
11. Mean Sprint Heart Rate	173.1600	8.5096	25
12. Mean Endurance (Total) Heart Rate	169.6198	7.2439	25
13. Mean Endurance (Using Arms) Heart Rate	172.0797	7.6922	25
14. Mean Endurance (No Arm Use) Heart Rate	167.5119	8.6268	25
15. Sprint Time (Sec.)	62.8000	8.2058	25
16. Endurance Time (Sec.)	485.3999	50.5816	25

VITA

DENNIS WAYNE ATEN

The writer was born in Holdrege, Nebraska in 1937 and grew up in many communities in Nebraska, South Dakota, Minnesota, Iowa and Kansas. He attended high school in Tabor, South Dakota where he lettered in football, basketball, baseball and track.

He entered Nebraska University in 1955 majoring in physical education with a biological science minor. During his four years at Nebraska he participated in baseball and wrestling, was a member of Phi Epsilon Kappa, and worked as a student athletic trainer for the health service.

After graduation with a B. S. in Education he continued his education at the Hermann School of Physical Therapy in Houston, Texas. He graduated number one in his class in the fall of 1960 and accepted a job with U. S. Air Force Academy as assistant athletic trainer. In December, 1964 he became Executive Director of the Winneshiek County Physical Therapy Center, Inc. and athletic trainer at Luther College in Decorah, Iowa. While in Decorah he was active in his state and national professional organization, as national delegate and chairman of student affairs and recruitment committee. He also held advisory and delegate positions to the Iowa Easter Seal Society.

In 1968 he moved to Charleston, Illinois where he became athletic trainer and instructor in physical education at Eastern Illinois University. Here he started work on his Master of Science Degree in Physical Education. He is currently assistant editor for the Journal of the National Athletic Trainers Association and chairman of an ad hoc committee on facilities for the same organization.

The writer is married to the former NaDean Haase and has three children; Keith 12, Kevin 10, and Lori 2.